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KEY PECKING OF PIGEONS UNDER VARIABLE-INTERVAL SCHEDULES OF BRIEFLY SIGNALED DELAYED REINFORCEMENT: EFFECTS OF VARIABLE-INTERVAL VALUE

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Key pecking of 4 pigeons was maintained under a multiple variable-interval 20-s variable-interval 120-s schedule of food reinforcement. When rates of key pecking were stable, a 5-s unsignaled, nonresetting delay to reinforcement separated the first peck after an interval elapsed from reinforcement in both components. Rates of pecking decreased substantially in both components. When rates were stable, the situation was changed such that the peck that began the 5-s delay also changed the color of the keylight for 0.5 s (i.e., the delay was briefly signaled). Rates increased to near-immediate reinforcement levels. In subsequent conditions, delays of 10 and 20 s, still briefly signaled, were tested. Although rates of key pecking during the component with the variable-interval 120-s schedule did not change appreciably across conditions, rates during the variable-interval 20-s component decreased greatly in 1 pigeon at the 10-s delay and decreased in all pigeons at the 20-s delay. In a control condition, the variable-interval 20-s schedule with 20-s delays was changed to a variable-interval 35-s schedule with 5-s delays, thus equating nominal rates of reinforcement. Rates of pecking increased to baseline levels. Rates of pecking, then, depended on the value of the briefly signaled delay relative to the programmed interfood times, rather than on the absolute delay value. These results are discussed in terms of similar findings in the literature on conditioned reinforcement, delayed matching to sample, and classical conditioning.

Key words: brief signal, conditioned reinforcement, delay of reinforcement, variable-interval schedules, key peck, pigeons

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Delaying reinforcement of free-operant behavior produces different results depending on specific features of the experimental situation. Reductions in response rates are observed if the delays are unsignaled and nonresetting (cf. Catania & Keller, 1981), sometimes even if the delays are as short as 1 s (Schaal & Branch, 1988; Sizemore & Lattal, 1977; Williams, 1976). However, if delays are signaled (i.e., the response that begins the delay also produces a change in external stimulation), delays as long as 1 min can have little effect on response rates (Ferster, 1953; Lattal, 1984; Schaal & Branch, 1988, 1990). Schaal and Branch (1988) showed that, at short delay values, brief changes in stimulation that accompany the start of the delay (i.e., brief signals) maintain levels of responding comparable to those obtained when the delay-correlated stimulus is present throughout the delay (i.e., complete signals). Response rates under conditions with brief signals decrease, however, at longer delay values, under which complete signals continue to maintain relatively high rates. In addition, predelay response rates are an increasing function of the proportion of the delay that is signaled (Schaal & Branch, 1990).

Schaal and Branch (1988, 1990) have suggested that the temporal and correlative relation between a delay signal and food may be most important in establishing its conditioned reinforcing function. Under this interpretation, briefly signaled delayed reinforcement procedures are analogous to trace conditioning procedures, in which a conditional stimulus (CS) is presented for a time then removed, and an unconditional stimulus (US) is presented after a CS-US interval (or delay) has elapsed (see also Lattal, 1987, p. 114). Whether the keylight stimulus as a CS comes to control

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approach and/or key pecking (as in a trace autoshaping paradigm) or maintains relatively high rates leading to its presentation (as in a briefly signaled delayed reinforcement paradigm) depends on whether its presentation is made contingent on behavior.

If Pavlovian relationships between delay signals and reinforcement are important determinants of the effectiveness of the signals, then the maximum delay at which delay signals should maintain relatively high response rates should depend on the average time between food presentations (Gibbon, Baldock, Locurto, Gold, & Terrace, 1977; Kaplan, 1984). For example, Kaplan (1984), exploring trace autoshaping with pigeons, showed that the minimum CS-US interval required to produce key pecking or keylight approach increased as the interfood interval increased. This suggests that the function of a brief delay signal should depend, not on the absolute delay to reinforcement, but on the delay interval relative to the time between reinforcers. This is precisely the prediction of a model of conditioned reinforcement strength common in the literature of operant behavior, the delay-reduction hypothesis (Fantino, 1977; Squires & Fantino, 1971). Although this model was developed to predict relative response rates under concurrent chains schedules, there is reason to assume that the model can also help understand changes in response rates under the conditions studied here.

In the present experiment, briefly signaled delays to reinforcement were varied across conditions in a two-component multiple schedule. In the first component, immediate or delayed food was presented according to a variable-interval (VI) 20-s schedule; in the second component, a VI 120-s schedule operated. Equal delays between components were arranged in most conditions.

METHOD

Subjects

Four experimentally naive adult female White Carneau pigeons (*Columba livia*) were used in this experiment. They were maintained near 80% of their free-feeding weights via supplemental feedings after experimental sessions. When not in experimental sessions they were housed individually in a temperature-controlled colony where they were allowed free access to water and digestive grit.

Apparatus

Two standard Lehigh Valley Electronics pigeon conditioning chambers (Model 1519) were used. Their internal dimensions were 30.5 cm long, 35.5 cm wide, and 35 cm deep. The front walls were brushed aluminum panels with three response keys (2.5 cm diameter) centered side-to-side 24.5 cm above wire-mesh floors. Only the middle keys, which could be lit from behind with red, green, pale blue, or amber lights, were used; the side keys were dark and inoperative. Middle keys required a force of approximately 0.14 N to produce a 50-ms feedback tone (Mallory Sonalert) and be recorded as a response. Twenty-eight-volt 1.1-W lamps 8 cm directly above the middle keys served as houselights. Rectangular apertures 9 cm below the middle keys provided access to solenoid-operated food hoppers. During hopper presentations this aperture was lit with white light, and houselights and keylights were extinguished. White noise and noise from a ventilation fan helped to mask extraneous sounds. Contingencies were programmed and data were collected by a Zenith® 286-LP-40 microcomputer, programmed under MED-STATE Notation® (MED Associates, Inc. & Tatham, 1988) software. The temporal locations of responses and reinforcers were recorded individually and were used to construct cumulative records using Soft Cumulative Record® software.

Procedure

Experimental sessions were conducted 6 or 7 days per week at approximately the same time each day. Following two 30-min periods during which pigeons were placed in the experimental chamber with only the houselight on (adaptation), the pigeons were trained to eat from the magazine. Key pecking was shaped via the method of successive approximations. After a single session in which each peck produced 3-s access to the hopper, pigeons were exposed to the terminal schedule, a multiple VI 20-s (green key illumination) VI 120-s (red key illumination) schedule of immediate reinforcement. The VI schedules were made up of 24 interval values determined using Catania and Reynolds' (1968, Appendix II) constant-probability method. Actual interval values were increased gradually across the first four sessions. Sessions began with the illumination of the houselight, illumination of the middle key by green, and the operation of the VI 20-s schedule. The first peck after each interval elapsed extinguished the houselight and keylight, illuminated the light above the hopper, and raised the hopper for 3 s. After eight food presentations in the first component, all lights were extinguished for 30 s, followed by illumination of the houselight and the red keylight associated with the VI 120-s schedule. The second component also lasted for eight food presentations. This sequence was repeated three times before the session was terminated.

After key-pecking rates stabilized, as judged by visual inspection, a 5-s unsignaled nonresetting (cf. Catania & Keller, 1981) delay was arranged between the first peck after an interval elapsed and the presentation of food. No change in external stimulation accompanied the delay, and pecks during the delay continued to produce a feedback tone and were counted, but had no effect on the presentation of food. Once pecking rates stabilized under this procedure, a 0.5-s change in keylight color accompanied the peck that began the delay. In the VI 20-s component, the keylight color changed from green to amber, then back to green for the remaining 4.5 s. In the VI 120-s component, the keylight color changed from red to pale blue, then back to red for the remaining 4.5 s. All other circumstances were the same as in the previous condition. In the next condition the delay, still briefly signaled, was increased to 10 s in both components. When rates had become stable, the delay was increased again to 20 s in both components. The next condition was a control condition; because reinforcement rates were reduced by at least 50% in the VI 20-s component with a 20-s delay relative to the VI 20-s with no delay (a considerably larger proportional reduction than in the VI 120-s component), a VI 35-s schedule with a 5-s delay was arranged for this component. This helped determine that the increase in the delay, rather than the decrease in the nominal reinforcement frequency, was responsible for the effects observed in the VI 20-s component. Subsequently, some of the previous conditions were replicated. Table 1 lists the conditions in the order in which they were presented for each subject, the number of sessions in each condition, and the reinforcement rates obtained in the final five sessions of each condition for each component (with standard deviations).

RESULTS

Cumulative records of the key pecking of Pigeon 555 from the final sessions of the initial condition without delays, the condition with 5-s unsignaled delays, and the conditions with brief signals are shown in Figure 1. Rates and patterns of key pecking under the condition without delays were typical of those obtained on VI schedules, with rates on the VI 20-s schedule generally higher than those obtained on the VI 120-s schedule. Lower key-peck rates and erratic patterns were observed under the condition with unsignaled delays. When 5-s delays were briefly signaled, however, response rates and patterns were similar to those observed under conditions without delays. Under conditions with 20-s briefly signaled delays, rates of pecking during the VI 20-s component fell to low levels and patterns of pecking resembled those observed under the condition with unsignaled delays; these measures changed little under the VI 120-s schedule.

Rates of key pecking prior to delays, presented as the mean of the final 10 sessions of each condition (± 1 *SD*), are depicted in Figure 2. When 5-s unsignaled delays were appended to the VI schedules (plotted above "5/US"), rates decreased relative to those observed under immediate-reinforcement conditions. The magnitude of the decreases ranged from approximately 25% of immediate-reinforcement levels for Pigeons 555 and 444 to a very slight decrease (with some points overlapping) in the mean rates under the VI 20 s for Pigeon 888. When 5-s delays were briefly signaled (plotted above "5 s"), rates increased to levels near those obtained under conditions with immediate reinforcement (i.e., baseline), except for Pigeon 888, for which rates in the VI 120-s component under the initial immediate-reinforcement condition were unusually high (see filled circle over "0 s"). Immediate-reinforcement conditions were presented again during the final phase for this pigeon (filled triangle); this time rates were nearer those obtained on this schedule during the rest of the experiment. Key-peck rates in both components remained near baseline levels during conditions with 5- and 10-s delays (except for Pigeon 555, for

Table 1

Order of conditions, number of sessions per condition, and reinforcers per minute (means of the last five sessions of each condition; standard deviations in parentheses) for each pigeon.

Condition	Subject	Sessions	Reinforcers/minute Component 1	Reinforcers/minute Component 2
Mult VI 20 s VI 120 s	111	32	2.75 (0.26)	0.49 (0.01)
	444	28	2.98 (0.16)	0.49 (0.01)
	555	31	2.89 (0.29)	0.49 (0.00)
	888	35	2.94 (0.17)	0.49 (0.01)
Unsignaled 5-s delay to reinforcement	111	42	1.82 (0.17)	0.43 (0.01)
	444	23	2.05 (0.20)	0.41 (0.04)
	555	56	2.08 (0.14)	0.47 (0.00)
	888	78	2.37 (0.05)	0.47 (0.01)
0.5-s delay signal, 5-s delay	111	75	2.34 (0.12)	0.47 (0.01)
	444	62	2.41 (0.02)	0.48 (0.00)
	555	61	2.40 (0.05)	0.48 (0.00)
	888	37	2.45 (0.01)	0.48 (0.00)
0.5-s delay signal, 10-s delay	111	26	1.94 (0.05)	0.45 (0.01)
	444	30	2.00 (0.02)	0.46 (0.00)
	555	73	1.72 (0.04)	0.46 (0.00)
	888	39	2.03 (0.01)	0.46 (0.00)
0.5-s delay signal, 20-s delay	111	46	0.80 (0.12)	0.41 (0.01)
	444	28	0.99 (0.11)	0.42 (0.00)
	555	24	1.18 (0.09)	0.42 (0.01)
	888	34	1.44 (0.02)	0.43 (0.00)
1. VI 35 s FT 5 s (briefly signaled)	111	53	1.44 (0.02)	0.41 (0.01)
	444	31	1.46 (0.01)	0.42 (0.00)
2. VI 120 s FT 20 s (briefly signaled)	555	30	1.46 (0.01)	0.42 (0.00)
	888	30	1.48 (0.01)	0.42 (0.00)
0.5-s delay signal, 20-s delay	111	77	1.10 (0.22)	0.42 (0.02)
	555	52	1.20 (0.10)	0.42 (0.03)
0.5-s delay signal, 5-s delay	444	31	2.31 (0.05)	0.47 (0.00)
Mult VI 20 s VI 120 s	444	19	2.99 (0.01)	0.47 (0.00)
	888	24	2.98 (0.01)	0.49 (0.00)

which rates in the VI 20-s component during the condition with 10-s delays decreased to about 50% of baseline levels). When delays were 20 s, rates in the VI 120-s component were largely unaffected; Pigeon 444's key-pecking rates fell to approximately 70% of immediate-reinforcement levels, the largest decrease in rates under the VI 120-s schedule. In the VI 20-s component, rates fell to low levels, ranging from 13% (for Pigeon 111) to 50% (for Pigeon 888) of baseline levels.

When the VI schedule in the "short-VI" component was increased to 35 s and the delay was decreased to 5 s (plotted over "5/20 s"), thus matching the nominal reinforcement frequency arranged in the previous condition with 20-s delays, response rates approached or matched baseline levels. When conditions with 20-s delays were repeated (Pigeons 111 and 555), key-peck rates approached those obtained during the first exposure to this condition, although rates in the VI 120-s component for Pigeon 555 were about 30% less than those observed initially. Replications of 5-s briefly signaled delay conditions and immediate-reinforcement conditions for Pigeon 111 produced effects near those obtained initially.

Figure 3 shows key-pecking rates for each pigeon during delays (means of the final 10 sessions of each condition, ±1 *SD*). Relatively low rates were observed for Pigeons 444 and 111 (10 responses per minute are less than one response per delay under 5-s delays; 35 responses per minute are about six pecks per delay). On the other hand, relatively high rates

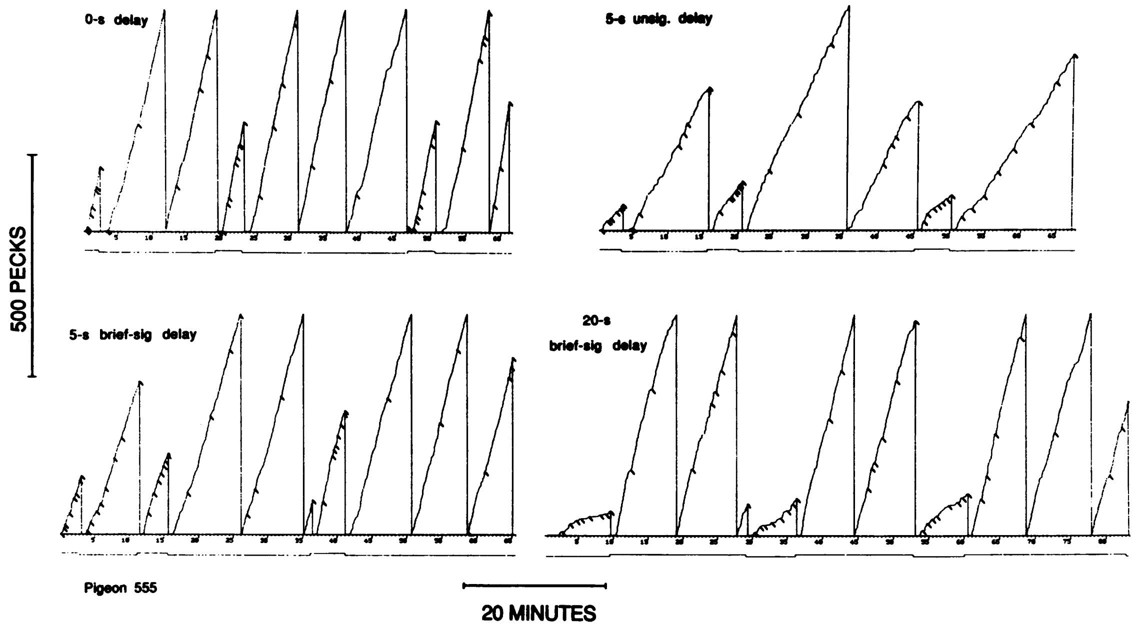

Fig. 1. Cumulative records of the key pecking of Pigeon 555 under conditions with immediate reinforcement (top left panel), 5-s unsignaled delayed reinforcement (top right panel), 5-s briefly signaled delayed reinforcement (lower left panel), and 20-s briefly signaled delayed reinforcement (lower right panel). Diagonal deflections of the response pen indicate food deliveries. In three of the panels, the VI 20-s component operated when the event pen was up and the VI 120-s component operated when the event pen was down; in the bottom right panel, this arrangement is reversed. Numbers along the *x* axes indicate time in minutes.

were observed for Pigeons 555 and 888, in many cases higher than those observed prior to delays. Pecking rates during delays roughly matched predelay rates in the VI 20-s component for Pigeon 555 but decreased in the VI 120-s component when no change in predelay rates was observed. Response rates during delays were consistently higher than predelay rates in the VI 20-s component for Pigeon 888, even when predelay rates decreased, whereas rates during the VI 120-s component were roughly similar to predelay rates.

Table 1 shows that reinforcement rates decreased after each increase in the value of the delay. Reinforcement rates in the VI 120-s component ranged from 0.49 reinforcers per minute under conditions with immediate reinforcement to 0.41 reinforcers per minute during conditions with 20-s delays. Reinforcement rates in the VI 20-s component ranged from 2.75 reinforcers per minute under conditions with immediate reinforcement to from 0.8 (for Pigeon 111) to 1.44 (for Pigeon 888) reinforcers per minute during the condition with 20-s delays. When the VI was changed to a VI 35 s and the delay reduced to 5 s, thus producing nominally similar reinforcement frequencies, response rates increased to near those obtained under immediate reinforcement. This increase resulted in increased reinforcement rates (about 1.45 reinforcers per minute in all pigeons).

DISCUSSION

Key-pecking rates obtained under the VI 120-s component changed little as briefly signaled delays were increased from 5 to 20 s and were generally similar to those obtained under conditions with immediate reinforcement. In contrast, response rates in the VI 20-s component generally were considerably lower when the delay was 20 s (and 10 s for Pigeon 555) than during conditions with shorter delays or no delay at all. Whether key-pecking rates were maintained at high levels under briefly signaled delayed reinforcement, then, depended on the delay *relative to* interfood times. After considering three features of the current data, this discussion will focus on possible con-

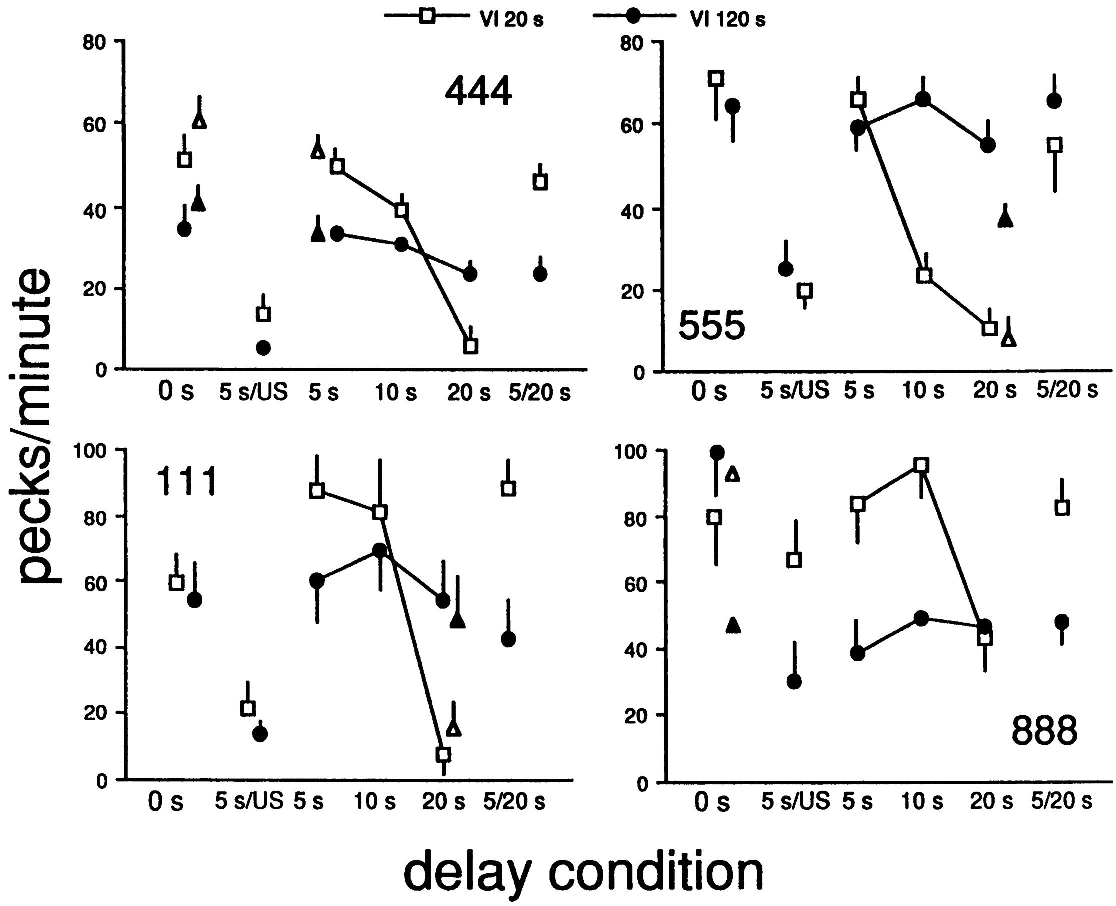

Fig. 2. Response rates prior to delays as a function of delay condition for each subject. Points depict means from the final 10 sessions of each condition; vertical bars represent one standard deviation. Rates under the VI 20-s schedule are depicted by open squares (replications depicted by open triangles). Rates under the VI 120-s schedule are depicted by filled circles (replications depicted by filled triangles). Points above "O s" were obtained under immediate-reinforcement conditions, points above "5 s/US" were obtained under the condition with 5-s unsignaled delays, and points above "5 s," "10 s," and "20 s" were obtained under briefly signaled delayed reinforcement conditions. Points above "5/20 s" were obtained under condition in which Component 1 was associated with a VI 35-s schedule of 5-s briefly signaled delayed reinforcement.

nections between this research and research in classical conditioning, delayed matching to sample (DMTS), and choice and conditioned reinforcement.

First, the variability across subjects and conditions in the rate of pecking during delays (Figure 2) is characteristic of previous research in this area (Schaal & Branch, 1988, 1990). Indeed, in one study (Pierce, Hanford, & Zimmerman, 1972) planned variability in behavior during delays (e.g., high lever-pressing rates arranged with a fixed-interval schedule or low rates arranged with an interresponse time $>t$ schedule) had no effect on the predelay lever pressing of rats on a VI 60-s schedule. The only consistent relationship between pre- and intradelay rates observed in experiments like the one performed here is that, in general, when predelay response rates are low, intradelay response rates are also low. When predelay response rates are high, intradelay response rates have ranged from zero to extremely high levels (e.g., about seven pecks per second for Pigeon 269 in Schaal & Branch, 1990). The variability in behavior during the delay is somewhat distressing, because a consistent effect might help to evaluate interpretations of the function of the delay signal. For example, conditions in which high response rates during the VI are obtained are not consistently con-

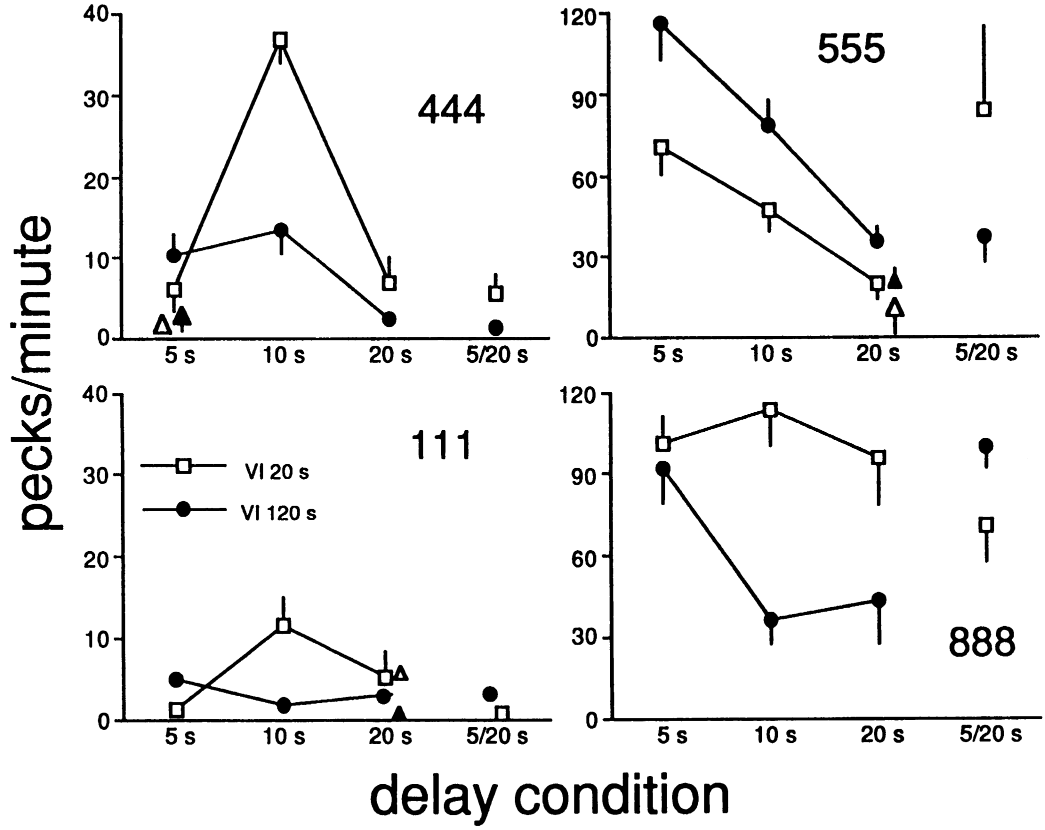

Fig. 3. Response rates during delays as a function of delay condition for each subject. Points depict means from the final 10 sessions of each condition; vertical bars represent one standard deviation. All other details are identical to those in Figure 2.

ditions in which high rates of pecking the delay signal are obtained (Schaal & Branch, 1988, 1990). This seems to be inconsistent with an interpretation of the signal's effect based on classical conditioning, but conclusions about the discriminative function of the delay signal are also difficult to make given these data. Perhaps it does not make much sense to say things like "the brief signal acquires a CS function, and, therefore, is a conditioned reinforcer," or, "the brief signal serves as a discriminative stimulus, and therefore maintains high predelay response rates," when how the signal functions depends on the relationship the experimenter arranges between it and behavior. The present procedure seems particularly suited to observing the conditioned reinforcing function of a stimulus, but other procedures are better suited for the observation of discriminative and eliciting stimulus functions. One might try to combine procedures to observe more than one function at a time. The sample in delayed matching to sample (DMTS), for example, might be presented according to a VI schedule; if the functions that relate VI response rates and matching accuracy to other variables (e.g., delay or retention interval) are very similar, we might conclude that the conditioned reinforcing and the discriminative functions of the signal/sample are related. However, we could not logically say that the signal's conditioned reinforcing function depended on its discriminative stimulus function. In all of these situations, a more fundamental variable, one that determines whether a stimulus will function in some way, is the temporal or correlative arrangement of events.

Second, different temporal contexts were confounded with different delay signal colors in the present experiment. A test of whether classical conditioning underlies the conditioned reinforcing function of the delay signal may be to use the same signal color in the two components. By virtue of the favorable temporal context of the signal in the VI 120-s component, the signal might be expected to maintain higher rates in the VI 20-s component than those obtained in the present experiment. On the other hand, replication of the present results might suggest that other processes are involved. However, research on "occasion setting" in classical conditioning shows that a stimulus (S1) will elicit more responding if it is preceded by another stimulus (S2) that signals a contingency between S1 and food (Ross & Holland, 1981; Thomas, Robertson, Cuniffe, & Lieberman, 1989); subjects respond much less often to S1 when it is not preceded by the occasion-setting stimulus (and, hence, is not followed by food). Because VI schedules were correlated with keylights of different color, the brief signal in the present procedure may be subject to a similar type of conditional control. A result similar to the present one using identical delay signals, then, might be expected based on research in classical conditioning.

Third, although changes in reinforcement frequency accompanied each change in delay value, it is difficult to account for the magnitude of the rate decreases under the VI 20-s schedule in terms of these changes, because rates increased to near baseline levels under the condition with the VI 35-s schedule with 5-s signaled delays, which equated nominal reinforcement frequencies.

There are several experimental paradigms that produce a kind of stimulus control that may be involved in the effectiveness of the delay signal in the present procedure. For example, the present procedure is very similar to trace autoshaping, the major difference being the dependency between presentation of a keylight stimulus (and subsequent food presentation) and key pecking. Results of experiments employing these two procedures suggest that similar process are involved. "Elicited" key pecking in trace autoshaping arrangements becomes less likely as the interval between CS presentation and food is lengthened (Lefrancois & Lattal, 1987; Lucas, Deich, & Wasserman, 1981). Similarly, key-pecking rates under briefly signaled delayed reinforcement conditions are near immediate reinforcement levels at short delay values, but decrease to low levels as the delay is increased (Schaal & Branch, 1988). Also, delay conditioning (in which the CS is presented and remains until the US is presented) is more likely to result in autoshaped behavior than is comparable trace conditioning (Newlin & LoLordo, 1976). Likewise, higher predelay pecking rates are obtained when delays are completely signaled (i.e., the signal follows pecking and is present until food is delivered) at delay values resulting in low rates under briefly signaled delay conditions (Schaal & Branch, 1988, 1990). Third, the higher the correlation between presentations of a keylight and food, the more likely autoshaped behavior will be observed (Gibbon, Locurto, & Terrace, 1975). A perfect correlation between brief delay signals (and complete delay signals; Lattal, 1984) and food presentation has been shown to result in much higher rates of pecking than arranging no correlation between them (Schaal & Branch, 1989[1]). Finally, Kaplan (1984) showed that trace conditioning depended not on the absolute CS-US interval but on this interval relative to interfood times; as interfood times were increased, progressively longer CS-US intervals resulted in conditioning (see also Gibbon et al., 1977). In the present experiment a similar result was obtained; conditions with 20-s delays produced low rates of pecking under a VI 20-s schedule, but rates were not appreciably changed under the VI 120-s schedule. These observations prompted Schaal and Branch (1988, 1990) to suggest that the effects of the brief signal in the present procedure and a keylight CS in trace autoshaping reflect the same processes.

However, the greater importance of the relative versus the absolute delay to reinforcement has been observed in several experimental situations. For example, in studies of choice employing concurrent chains schedules, the immediacy of the reinforcer delivered in the terminal link is best expressed relative to the average time between reinforcers (Fantino, 1969, 1977; Squires & Fantino, 1971). Also, in DMTS procedures with pigeons, remembering of recently presented stimuli depends not on the absolute time between sample and

[1] Schaal, D. W., & Branch, M. N. (1989, May). *Responding of pigeons under variable-interval schedules of briefly signaled delayed reinforcement: Effects of signal-food correlation.* Paper presented at the meeting of the Association for Behavior Analysis, Milwaukee, WI.

comparison presentations but on that time relative to the intertrial interval (ITI; Grant, 1975; Maki, Moe, & Bierly, 1977; Roberts & Kraemer, 1982; Wilkie, 1984). Based on these observations, Wixted (1989) suggested that performance under DMTS might reflect the same processes controlling performance under concurrent chains schedules and thus conform to the delay-reduction hypothesis. In order to account for DMTS performance, Wixted amended the delay-reduction hypothesis by adding a variable that expresses the "retention interval" (i.e., t, the time between sample offset and the opportunity to choose between comparison stimuli). DMTS performance, then, is a function of the delay-reduction quantity (i.e., $T - d$, the average time between successive reinforcements minus the average delay to reinforcement associated with the sample stimulus) divided by the retention interval (excluding sensitivity parameters; Wixted, 1989). As the delay-reduction quantity becomes more favorable (as when, for example, the average time between reinforcements, T, is increased while d is kept constant), the deleterious effects on remembering the long retention intervals are lessened (i.e., pigeons remember over a longer interval when the time between trials is great). These are precisely the quantities that have been shown to be important in the present procedure. Specifically, rates of key pecking depend on the delay to reinforcement (Schaal & Branch, 1988; the present experiment), the average time between reinforcements (the present experiment), and, with the previous quantities held constant, the retention interval (i.e., the time between signal offset and food presentation; Schaal & Branch, 1990).

Many researchers have noted the generality of the effects of temporal context in controlling behavior but disagree about which type of relationship "underlies" performance in each circumstance. For example, some have differed with Wixted (1989) by suggesting that respondent relationships, such as those that govern autoshaping, also underly DMTS performance (Roberts & Kraemer, 1982; Santi, 1984; Wilkie, 1984). On the other hand, Fantino (1981, 1982) has suggested that the delay-reduction hypothesis may also account for the eliciting function of keylights in autoshaping procedures. It is not clear which approach should be preferred: one arising from autoshaping research, from research on remembering, or from research on choice and conditioned reinforcement. An integral feature of each, however, must be the primary role of the temporal context in determining the function of stimuli that signal delays to reinforcement. Parametric research, in which precise control over temporal contexts in the different experimental paradigms (assured, perhaps, through yoking the temporal arrangement of response-independent stimulus presentation to that obtained under conditions in which stimuli are presented response dependently), will be required both to evaluate the fit of proposed models and to determine the extent to which behavior under these conditions is actually under control of the same processes. At this point, it may be enough to note that the present data seem to reflect a very general principle of behavior: The temporal and correlative arrangement of stimuli largely determines whether they will assume some function, and the function that is observed (discriminative, eliciting, or reinforcing) depends on the relationships between their presentation and behavior.

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